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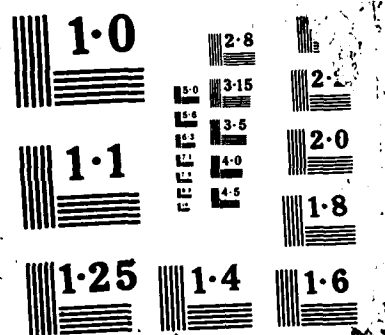
PROJECT SOAR EAGLE: WAVE FLYING THE GROB 103 SAILPLANE
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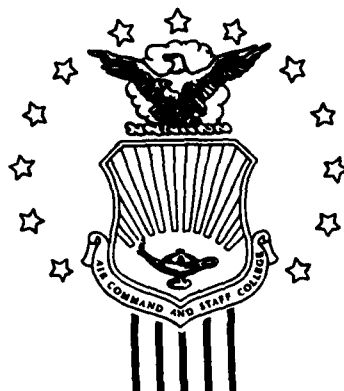
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STUDENT REPORT

PROJECT SOAR EAGLE:
WAVE FLYING THE GROB 103 SAILPLANE

MAJOR JAMES M. PAYNE 88-2070

"insights into tomorrow"

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REPORT NUMBER 88-2070

TITLE PROJECT SOAR EAGLE: WAVE FLYING THE GROB 103 SAILPLANE

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Submitted to the faculty in partial fulfillment of
requirements for graduation.

AIR COMMAND AND STAFF COLLEGE
AIR UNIVERSITY
MAXWELL AFB, AL 36112-5542

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT STATEMENT "A" Approved for public release; Distribution is unlimited.		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 88-2070			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION ACSC/EDC		6b. OFFICE SYMBOL (If applicable)		7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Maxwell AFB AL 36116-5542			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
			WORK UNIT ACCESSION NO.		
11. TITLE (Include Security Classification) PROJECT SOAR EAGLE: WAVE FLYING THE GROB 103 SAILPLANE (U)					
12. PERSONAL AUTHOR(S) Payne, James M., Major, USAF					
13a. TYPE OF REPORT		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) 1988 April	
				15. PAGE COUNT 39	
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Project Soar Eagle is the U.S. Air Force Test Pilot School effort to break the world absolute altitude record for gliders. TPS initiated the project in 1981 and flew a modified Blanik L-13 from late 1983 until 1985. In 1986 the project team replaced the Blanik with a modified Grob G-103, a sailplane better suited to the mission. A Project Soar Eagle pilot has soared the Grob to 42,200 feet in the mountain wave generated by the Sierra-Nevada Mountains. This report documents and analyzes the Grob G-103 sailplane, the avionics, the life support systems (full pressure suit), and the flight operations used by Project Soar Eagle. The purpose of the report was to provide a blueprint from which the project could be duplicated, to provide a project history, and to aid the safe, successful conclusion of the project.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS				21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL ACSC/EDC Maxwell AFB AL 36112-5542				22b. TELEPHONE (Include Area Code) (205) 293-2867	
				22c. OFFICE SYMBOL	

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

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PREFACE

Project Soar Eagle is the U.S. Air Force Test Pilot School effort to break the world absolute altitude record for gliders. TPS initiated the project in 1981 as a response to a Headquarters USAF request for pioneering aviation flights. Project pilots flew record attempts in a modified Blanik L-13 from late 1983 until 1985. In 1986 the project team replaced the Blanik with a modified Grob G-103. This sailplane is better suited to the mission. A Project Soar Eagle pilot has soared the Grob to 42,200 feet in the mountain wave generated by the Sierra-Nevada Mountains.

This report documents and analyzes the Grob G-103 sailplane, the avionics, the life support systems, and the flight operations used by Project Soar Eagle. The purpose of the report is to provide a blueprint from which the project could be duplicated, to provide a project history, and to aid the safe, successful conclusion of the project.



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ABOUT THE AUTHOR

Major James M. Payne is an accomplished glider pilot and test pilot. During 1971 he soloed in gliders at the U.S. Air Force Academy. While a senior, he wrote a paper, "High Altitude Sailplane Flight," which studied the feasibility of breaking the glider world altitude record. It advocated adding a pressure suit system to the Schweizer 2-25 sailplane. Upon graduation, he was named the Outstanding Cadet in Soaring, Class of 1974. During 1,300 hours of glider flight, he has set 12 U.S. national soaring records, numerous state records, and won several contests. He has a Diamond Badge and a Triple Lennie Pin. He is Team Manager for the U.S. International Soaring Team. He has published a book, Buying a Used Sailplane, and several articles about soaring in American, Australian, and Italian journals. One article won the 1984 Paul Tuntland Award for "an important contribution to the science of soaring flight."

Major Payne won the Orville Wright Achievement Award while earning his pilot wings at Laughlin AFB, Texas. He received the Outstanding Aircraft Commander Award at F-4 training. After tours flying Phantoms in North Carolina and Iceland, Jim went to F-5E Enemy Weapons School where he was Top Gun. After an F-5 Aggressor tour in England, he attended the AFIT/TPS Education Program where he earned a Masters of Aeronautical Engineering and was a distinguished graduate of Test Pilot School. He then spent two years as test pilot and deputy director of the F-16XL flight test program. During his last assignment, he was a F-4/T-38/U-6 and glider instructor pilot at TPS. He was project manager for Project Soar Eagle during 1986 and 1987.

TABLE OF CONTENTS

Preface.....	iii
List of Illustrations.....	vi
Executive Summary.....	vii
 CHAPTER ONE--INTRODUCTION.....	 1
 CHAPTER TWO--INCEPTION TO 1985.....	 3
Inception.....	3
The Blanik Sailplane.....	3
Description.....	3
Blanik Faults.....	4
Blanik Operations.....	6
Summary.....	6
 CHAPTER THREE--PHASE TWO--1986 TO 1987.....	 7
New Hardware.....	7
The Grob G-103.....	7
Avionics.....	8
Life Support Systems.....	10
Summary.....	12
Grob Flight Operations.....	12
 CHAPTER FOUR--ANALYSES.....	 15
General.....	15
The Grob G-103.....	15
Avionics.....	17
Life Support Systems.....	18
Operations.....	19
 CHAPTER FIVE--CONCLUSIONS.....	 23
 BIBLIOGRAPHY.....	 25
 APPENDICES.....	 27
Appendix A--Soar Eagle Grob G-103 Wiring Diagram.....	28
Appendix B--Phase One Flight History.....	29
Appendix C--Phase Two FLight History.....	30
Appendix D--Glossary.....	31

LIST OF ILLUSTRATIONS

FIGURES

FIGURE 1--Project Soar Eagle Patch.....	2
FIGURE 2--The Blanik L-13 Sailplane.....	4
FIGURE 3--The Blanik Front Cockpit Pallet.....	5
FIGURE 4--The Grob G-103 Sailplane.....	7
FIGURE 5--The Grob Front Instrument Panel.....	8
FIGURE 6--The Grob Configured for LOX System.....	10
FIGURE 7--The Pressure Suit.....	11
FIGURE 8--Map of Flying Area.....	13
FIGURE 9--A "Good" 500 Millibar Weather Chart.....	20
FIGURE 10--Sierra Mountain Wave on 18 March 1987.....	21



EXECUTIVE SUMMARY

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REPORT NUMBER 88-2070

AUTHOR(S) MAJOR JAMES M. PAYNE, USAF

TITLE PROJECT SOAR EAGLE: WAVE FLYING THE GROB 103 SAILPLANE

SUBJECT

Project Soar Eagle is the U.S. Air Force Test Pilot School effort to break the world absolute altitude record for gliders. TPS initiated the project in 1981 as a response to a Headquarters USAF request for pioneering aviation flights. Project pilots flew record attempts in a modified Blanik L-13 from late 1983 to 1985. In 1986 the Soar Eagle team replaced the Blanik with a modified Grob G-103. This sailplane is better suited to the mission which requires a climb to 50,480 feet above mean sea level. A Project Soar Eagle pilot has soared the Grob to 42,200 feet in the mountain wave generated by the Sierra-Nevada Mountains.

OBJECTIVES

This report documents and analyzes the Grob G-103 sailplane, the avionics, the life support systems (full pressure suit), and the flight operations used by Project Soar Eagle. The purpose of the report is to provide a blueprint from which the project could be duplicated, to provide a project history, and to aid the safe, successful conclusion of the project.

EXECUTIVE SUMMARY (CONTINUED)

CONCLUSIONS

Project Soar Eagle is a mature project. The project sailplane has flown to 42,200 feet. The environment encountered at this altitude was as hostile as the conditions at record altitudes. Given suitable weather (mountain wave), Project Soar Eagle can safely achieve the world absolute altitude record.

RECOMMENDATIONS

The following recommendations will increase the chances of success:

1. Acquire additional batteries to allow quick turnarounds.
2. Install a new aircraft radio antenna to improve effective transmission power.
3. Add trim weight to make the Grob G-103 more efficient.

The following would insure safe flight:

1. Continue to carefully inspect the canopy for cracks before each mission.
2. Continue to observe conservative indicated airspeeds, avoid abrupt control movements and maintain hold of the stick at high altitudes.
3. Incorporate the National 490 parachute.

Chapter One

INTRODUCTION

Project Soar Eagle is the U.S. Air Force Test Pilot School (TPS) effort to break the world absolute altitude record for gliders. TPS initiated the project in 1981 as a response to a Headquarters USAF request for pioneering aviation flights. Project pilots flew record attempts in a modified Blanik L-13 sailplane from late 1983 to 1985. In 1986 the project team replaced the Blanik with a modified Grob G-103. This sailplane is better suited to the mission which requires a climb to greater than 50,480 feet above mean sea level (MSL). A Project Soar Eagle pilot has soared the Grob to 42,200 feet in the mountain wave generated by the Sierra-Nevada Mountains.

This record flying is possible because of a unique weather phenomena called the mountain wave. This phenomena occurs when strong winds flow over mountains such as the Sierra. The wave motion imparted by the mountains cause strong vertical components in the wind. The highest altitude achieved in wave is the current record of 49,009 feet. The project goal is 50,480 feet because the international records organization, Fédération Aéronautique Internationale (FAI), requires a 3 percent increase.

This report documents and analyzes the Grob G-103 sailplane, the avionics, the life support systems, and the flight operations used by Project Soar Eagle. The purpose of the report is to provide a blueprint from which the project could be duplicated, to provide a project history, and to aid the safe, successful conclusion of the project.



Figure 1. Project Soar Eagle Patch

Chapter Two

PHASE ONE--INCEPTION TO 1985

INCEPTION

The world absolute altitude record for gliders is a goal sought by many glider pilots. In 1963 the record soared to 46,267 feet. The current standard, set in 1986, is 49,009 feet. The pilots of those flights used pressure-demand oxygen systems with a maximum recommended altitude of 43,000 feet. Thus, those pilots exposed themselves to physiological danger.

Project Soar Eagle was a response to a request from Headquarters USAF for proposals for pioneering aviation flights. Test Pilot School has a glider program, and Edwards AFB has the depot for pressure suits. The TPS staff proposed to meld the suit and glider into a system that could safely break the 50,000 foot plateau. Planning began in 1981, and flight operations started in late 1983.

THE BLANIK SAILPLANE

Description

During the first phase, TPS used a Blanik L-13, a medium performance, two-place glider. TPS chose the Blanik because it met two criteria. It was available under the TPS glider contract and had adequate payload and space. TPS pilots flew the Blanik several times in the Tehachapi wave with a maximum achieved altitude of 34,600 feet MSL.

For a detailed description of the modified Blanik and Project Soar Eagle operations through 1984, see reference 8.

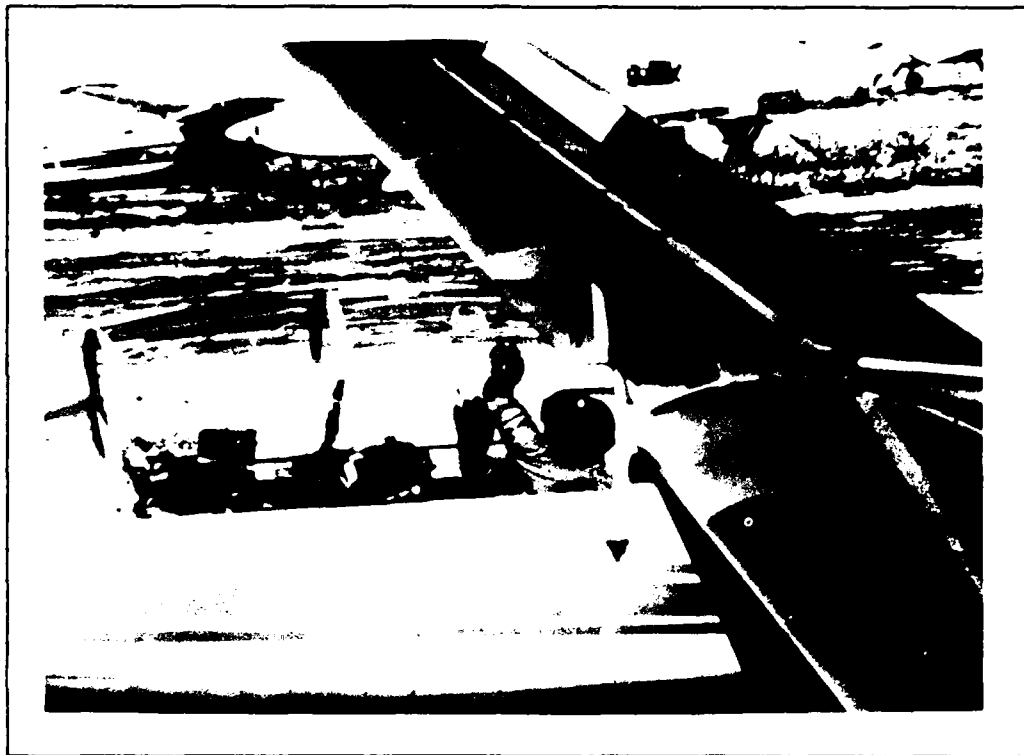


Figure 2. The Blanik L-13 Sailplane

Blanik Faults

The Blanik had several faults which made it unlikely to set the record. The worst fault was the measured performance of the particular Blanik used during this phase. When flight tested by TPS, its minimum sinking rate was 225 feet per minute (fpm), and its best glide ratio was 23-to-1. This was worse than the manufacturer's published values of 161 fpm and 28-to-1 respectively. In weak to moderate wave, even the degraded performance was adequate. In the strong winds associated with record mountain waves, a glider has to fly faster than the speed at which it achieves its minimum sinking rate. As the airspeed increases, the sink rate increases. At 75 knots indicated airspeed (KIAS), the Blanik was sinking 500 feet per minute. In order for the Blanik to climb when winds are equivalent to 75 KIAS, the lift had to be greater than 500 fpm. In addition to restricting the climbing ability of the Blanik, this poor performance resulted in large altitude losses during cross country flight. This restricted the cross range capability of the ship.

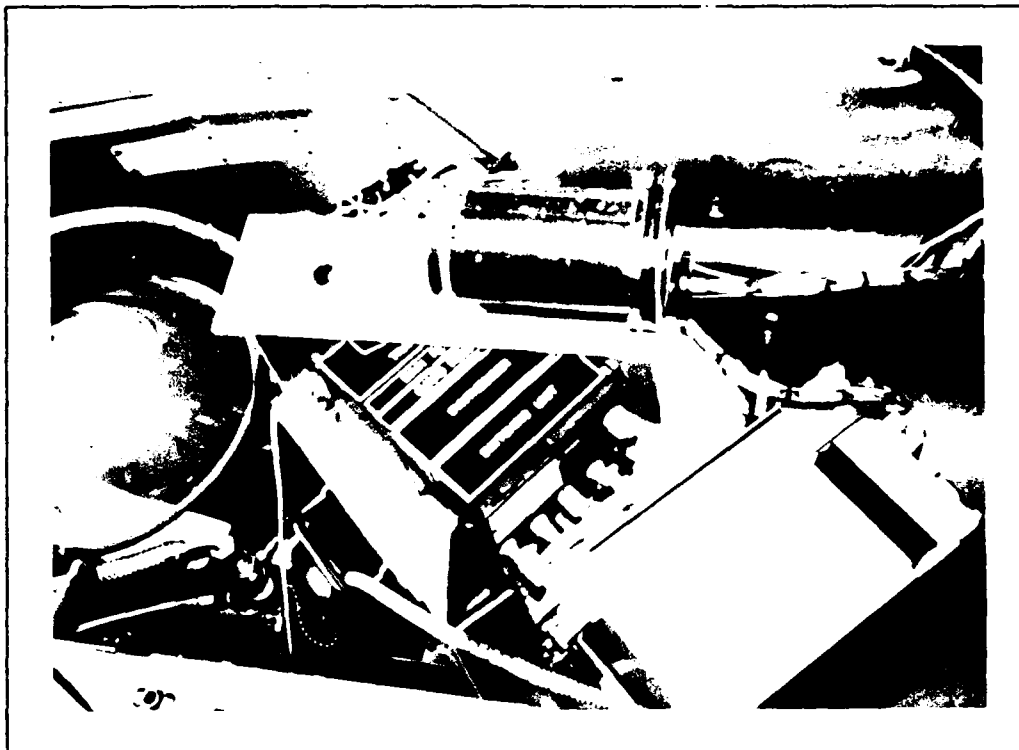


Figure 3. The Blanik Front Cockpit Pallet

The physical layout of the Blanik caused problems. Space limitations relegated the pilot to the rear cockpit. The visibility from the rear was not good. Ingress and egress were more difficult. The ergonomics were not good. It was colder in the rear due to leaks from the landing gear well.

Additionally, these space problems prevented the team from building the avionics and life support systems into the glider. They mounted them on a pallet which could be substituted for the front seat. The palletized system allowed normal student training when the Blanik was not on Soar Eagle sorties. Installing the pallet for sorties was a long task that significantly increased the launch time for record attempts. The layout of the pallet prevented the pilot in the rear cockpit from reaching most of the switches. For instance, he was unable to change the UHF radio frequency, necessitating single frequency operations. Also, he was unable to change the transponder code.

A 28-volt battery from a KC-135 powered the direct current electrical system. Without alternating current electricity, a liquid oxygen (LOX) quantity indication system

was not feasible. However, the team deemed the ten-liter supply more than adequate for planned operations.

A final fault of the Blanik was a political one. The Blanik was manufactured in the Warsaw Pact country of Czechoslovakia. The test team put up with this communist sailplane because it was the only adequate one available to the team.

Blanik Operations

Operationally, the team learned a lot from these early sorties. Most Blanik sorties originated from Fantasy Haven Gliderport at Tehachapi. Fantasy Haven is in the Tehachapi Mountains at a higher elevation than Edwards Air Force Base. When the mountain wave is working, a "cap cloud" often forms over the mountains that are causing the wave. Thus, the weather at Tehachapi can be foggy with low visibility when the wave is working. Meanwhile, the weather 30 miles downwind at Edwards is normally clear. After missing possible wave flights due to Tehachapi weather in the spring of 1985, the team started bringing the Blanik to Edwards.

During Blanik operations, project pilots discovered that the wave lift was often better from Inyokern north toward Bishop. However, the likelihood of being unable to return to Edwards due to poor Blanik performance prevented most operations this far north.

In the summer of 1985 an inspection of the Blanik N-number N157AS disclosed fatigue cracks in the tail. The interchangeability of the pallet paid off as the team switched to Blanik N-number N70AS for the fall 1985 missions.

Summary of Blanik

In summary, the Blanik had performance, pilot comfort, human factor and political faults. These led TPS to look for a better airframe.

Chapter 3

PHASE TWO--1986 TO 1987

NEW HARDWARE

The Grob G-103

In 1985 a Grob G-103 sailplane with N-number N38366 became available under the TPS contract. It promised to solve most of the faults of the Blanik and the test team set about equipping it for the mission.

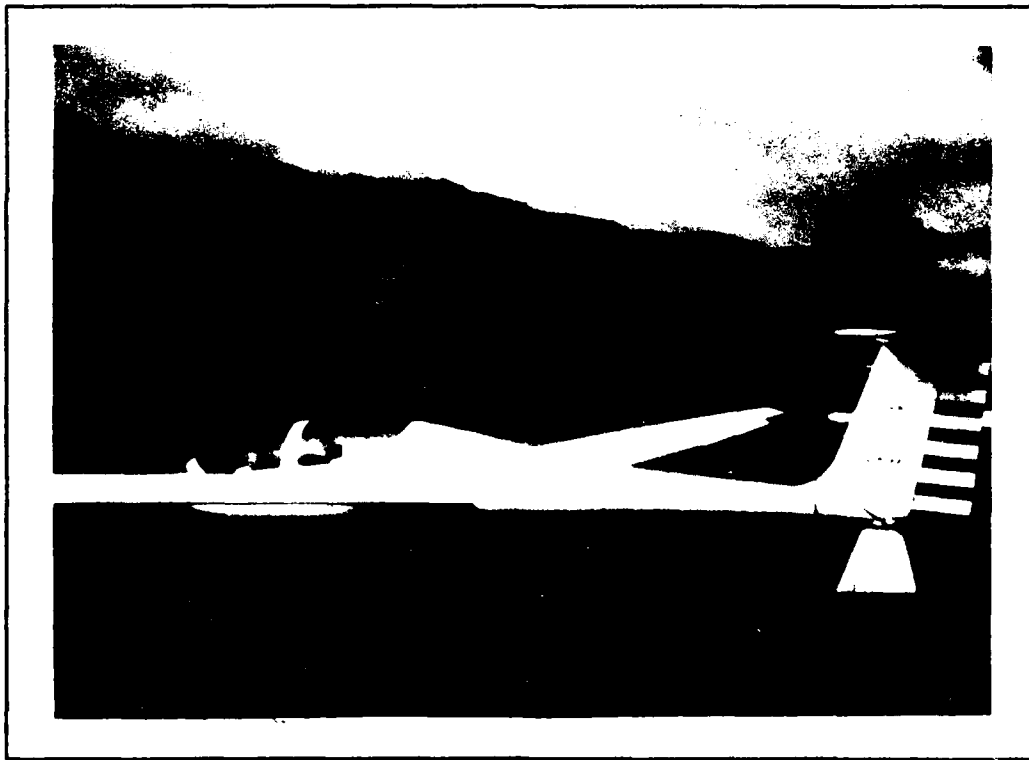


Figure 4. The Grob G-103 Sailplane

The Grob G-103 is a 17.5-meter span sailplane constructed primarily from fiberglass. It is a tandem, two-place design with a published glide ratio of 36-to-1. When TPS flight

tested a similar G-103, the best glide ratio was 31-to-1, and the minimum sink rate was 138 fpm. Importantly, the test sinking rate at 75 KIAS was 335 fpm, 33 percent better than the Blanik.

Avionics

Since the Grob had to be available for student training, the test team's goal was to permanently install required systems that did not interfere. For starters, they removed the original front cockpit instrument panel and cut a new one from aluminum. Items mounted in the new panel included a 80,000 foot altimeter, airspeed indicator, variometer (sensitive vertical velocity indicator), a turn needle, VHF radio, transponder, and required switches. Because of panel space limitations, the team mounted the magnetic compass and liquid oxygen quantity indicator on top of the glare shield. To protect Soar Eagle equipment from students, the team made an aluminum cover for the switches and avionics.

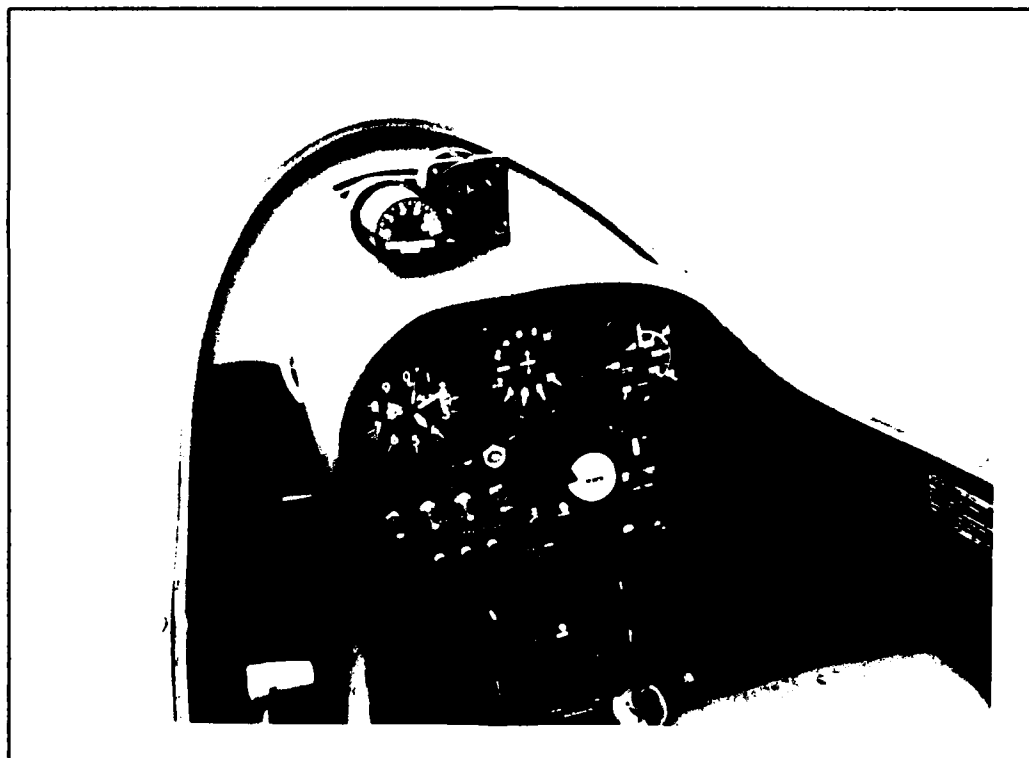


Figure 5. The Grob Front Instrument Panel

Safe conduct of the mission requires two way radio communication. The team chose a 14-volt, 720-channel Becker

AR 3201-2 VHF radio. It has a four frequency non-volatile memory. The radio has an intercom feature which makes two pilot operations possible. This also allows a pressure suit technician with a headset to communicate with a suited pilot during prelaunch checks.

The radio has an optional temperature sensor which the team mounted in the nose of the sailplane. This location in the fresh air vent at the extreme nose ensures correct sampling of the free airstream temperature.

The radio also has a built-in voltmeter. The team wired it to measure the voltage at the 14-volt bus.

Operations in the controlled airspace of Edwards' R-2508 restricted area mandate use of a radar transponder. A 14-volt Air-Sciences RT-887 digital transponder satisfied this need. It is a TSO'd (FAA approved) Class 1A transponder with 4096 reply code capability. The top of the rear cockpit glare shield served as an antenna mount. Aluminum tape on the bottom side of the fiberglass glare shield provided an antenna ground plane. A Terra AT 3000 Digitizer added altitude encoding to 30,000 feet. It fit behind the rear cockpit instrument panel.

A C-band beacon installation allowed the instrumentation radar at Edwards to track the Grob. The radars, Digital Instrumentation Radar (DIR) and FPS-16, have 100 and 30 foot circular errors respectively. This provided a backup to the barographs required for altitude verification. The beacon fit behind rear cockpit instrument panel. An aluminum plate under the rear cockpit seat served as antenna mount and ground plane.

For emergency letdown through cloud, the team chose a 28-volt turn needle from the F-4. They installed it in the front instrument panel and switched it to save power.

For electric power, the Edwards' Sheet Metal Shop built two custom 14-volt battery packs. They fit on each side of the rear cockpit instrument panel pedestal. This left enough legroom for a rear cockpit pilot in a pressure suit. The team wired the batteries in series to provide 14-volt and 28-volt direct current electricity. Circuit breakers, resettable in flight, provided circuit protection. A wiring diagram is in appendix A.

In 1987 the team fabricated a frame with two Arco G100 5.0 Watt, 14.5-volt solar panels. It fit over the rear cockpit seat. Wired in series, the panels provides a charge to the 28-volt electrical bus.

For alternating electricity, the team installed an inverter from a T-38. It provides 115-volt, 400-cycle power for the liquid oxygen quantity indication system. The five liter indicator came from the F-16 (Part Number (PN) 164-1). It required a special connector (PN 165-61-1026). To save power, the team wired the indicator with a "push to test" type button.

The 28-volt bus powers the pressure suit helmet face heat. A variable rheostat on the front panel allows the pilot to adjust the face heat to the minimum required.

Life Support Systems

The team removed the plywood floor of the baggage compartment behind the rear cockpit. They replaced it with a two-piece aluminum floor designed to hold the liquid oxygen bottle, the LOX heat exchanger, and the oxygen regulator. The liquid oxygen system was from the F-16. It incorporates a 5-liter bottle, a heat exchanger (PN 5E770-OCO), and a regulator.



Figure 6. The Grob Configured for LOX System

The LOX system supports the A/P 22F-6A Full Pressure Suit as used by SR-71 crews. The suit provides pilot protection to unlimited altitude. To keep the moisture-laden suit exhaust out of the cockpit, the physiological support team made a cover for the suit controller. A one-inch inside diameter plastic tube carries the exhaust from the cover to the rear of the baggage compartment.



Figure 7. The Pressure Suit

For an emergency oxygen system, the physiological support team chose the X-15 bailout oxygen system (PN F1327150). They mounted it in the parachute backpack between the harness and the canopy. During tests in the altitude chamber, this system provided 28 minutes of emergency oxygen and suit pressure. This is enough for bailout or letdown after a main oxygen system failure.

For emergency egress, the project chose a Security 150 parachute. A static line and an automatic opening barostat were added to the parachute to aid in egress. The static line activates the barostat which opens the parachute at or below 14,000 feet.

Summary of Grob

The team completed modifications to the Grob in March of 1986. The Edwards Weight and Balance Lab weighed the Grob and computed the center of gravity at planned loadings. The team completed ground and flight tests on 21 March 1986.

GROB FLIGHT OPERATIONS

Like the Blanik, Fantasy Haven was the base for the Grob. TPS ferried it to Edwards AFB for required maintenance and for wave flying when the forecast was good. This reduced the launch reaction time and minimized the chance of getting weathered in at Fantasy Haven. The team ferried the Grob by towing it with a contracted L-21 (Piper Super Cub). The contractor's facility at Tehachapi is about 25 minutes flying time from Edwards.

Rogers Dry Lake Runway 06/24 was the normal site of takeoffs and landings at Edwards AFB. This minimized the interruption of powered traffic and allowed the pilot to land directly into the wind. If the lakebed was closed, operations were on Taxiway Delta.

The T-46 Combined Test Force had extra hangar space. Since this hangar was near the lakebed, the TPS team stored the tow plane and glider there.

On days when the wave was working, the ground support personnel prepared the Grob. They moved it to the lakebed for takeoff while the pilot suited up. After pretakeoff checks in the cockpit, tow commenced. Until reaching sufficient altitude for an emergency landing, the tow remained over the lakebed. Then the tow proceeded directly to the area where the clouds indicated the wave was working. If the area west of Inyokern was the best looking, the glider pilot normally released there. After release, the tow pilot stayed in the area until the sailplane was climbing in the wave. If conditions were questionable, the tow pilot would land at Inyokern Airport and wait until the sailplane pilot was climbing. If the wave was not good, the Grob pilot would land at Inyokern and tow to Edwards.

The team used standard wave flying techniques. The highest flights started with a climb near Inyokern to an altitude of at least 25,000 feet. The pilot then traveled laterally in the wave toward the north. The best wave experienced by the team occurred on 18 March 1987. The team reached 42,200 feet east of Mount Whitney, 60 nautical miles north of Inyokern. Climb was on the order of 1,000 fpm at 10,000 feet with a gradual decrease in climb rate with altitude gain. By 35,000 feet, the climb rate was 300 fpm. The flight was 4.7 hours long and required 4.0 liters of LOX.

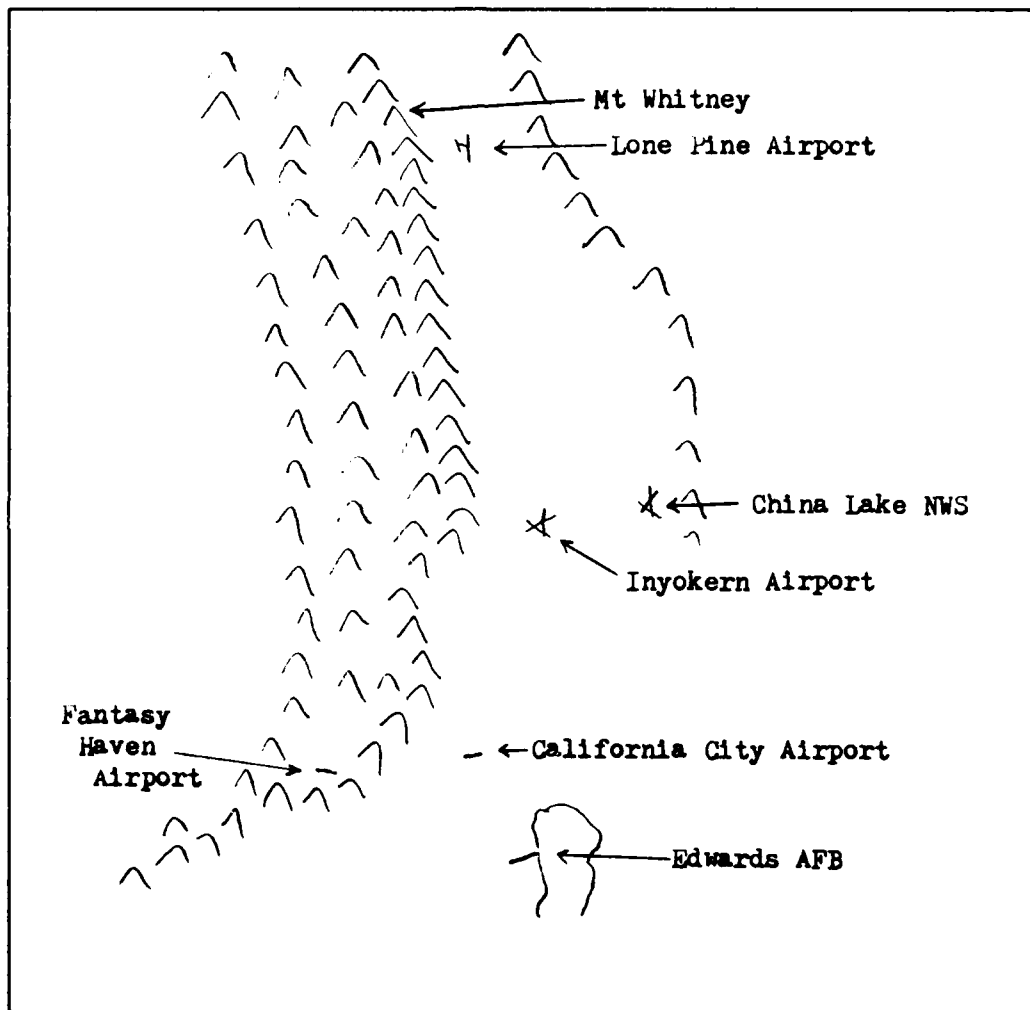


Figure 8. Map of Flying Area

Each mission continued until the pilot determined he was at the top of the wave or until LOX ran low. Upon termination, the pilots normally chose to fly to Edwards. On

days with a strong southwesterly component to the wind, getting back to Edwards was difficult. From Mount Whitney, the range to Edwards is 105 nautical miles. If the wind is southwesterly, 42,000 feet may not be enough to make it back. This required that the pilot attempt to fly in areas of wave lift as much as possible. Inyokern Airport and California City Airport offered landing sites en route. China Lake Naval Weapons Center offered the best emergency landing field with a flight surgeon.

The test team would normally meet the sailplane at the lakebed for landing. On the occasions where the pilot had cold feet, the flight surgeon met the glider to check for frostbite. The test team would secure the glider in the hangar while the physiological support team helped the pilot doff the pressure suit.

Chapter Four

ANALYSES

GENERAL

Analyzing Project Soar Eagle requires a look at four areas: the Grob, the avionics, the life support systems and operations. The analysis must determine whether the sailplane, its systems and crew can safely fly to altitudes above 50,000 feet. In addition to the hazards of normal sailplane operations, the study looks at the exposure to extremes of temperature and pressure that occur at high altitude. For instance, the lowest expected temperature is minus 68 degrees Fahrenheit. At 50,000 feet, the pressure is 1.7 pounds per square inch (psi) (1:416). This is one-ninth sea level pressure.

THE GROB G-103

Fiberglass sailplanes have been to high altitudes many times. The test team's research did not find any case of structural failure due to cold temperature. Some designs with flight control systems that use bushings around pushrods or pulleys and cables have had problems with control stiffness. Grob designed the G-103 with bellcranks and pushrods which are not affected by the cold. Normally, the only visible effect of the cold is cracking in the gelcoat (polyester paint). Slow, uniform changes of temperature minimize cracking. Normal climbs and prolonged descents are best.

Of problems caused by cold temperatures, canopy failure is the most dangerous. Shrinkage may cause the plexiglass to come out of the frame or the plexiglass to crack. If the failure results in wind blast, the pilot is in serious danger. The face heat system probably can not generate the thermal energy required to keep frost from the visor. The wind chill may cause frostbite or incapacitating hypothermia. However, the method of installation of the plexiglass in Grob canopy frames minimizes the danger. The installation uses metal fasteners through holes on the perimeter of the glass. The edge is then painted so it blends cosmetically with the frame.

The team should continue to carefully inspect the canopies before each flight. Any crack that threatens the integrity of a canopy is reason to abort. Pilots should keep climb and descent rates low enough to ensure gradual temperature changes.

The primary threat to the sailplane due to low pressure is flutter. Flutter occurs when the damping of the interactions of structural oscillations is too low. An example of flutter is an unstable interaction between the wing bending mode and the fuselage torsional mode. As altitude increases, the atmospheric changes affect the forcing function that causes flutter. In particular, constant indicated airspeed results in increasing true airspeed. TPS engineers analytically determined the maximum safe airspeed at 60,000 feet to be 105 knots equivalent airspeed (KEAS).

In 1986 Dr. Niedbal of West Germany did a flutter analysis of a 1,500 pound experimental category Grob G-103 up to 20,000 meters (65,630 feet). His antisymmetric analysis for this altitude shows a possible instability between the rudder and fuselage torsion as slow as 230 kilometers per hour (kph). This equates to 107 knots. The symmetric analysis shows stability to 400 kph (216 knots) with additional counter balance in the ailerons and rudder (9). Dr. Niedbal does not state whether he used indicated, equivalent or true airspeed in his analysis. If he is using equivalent airspeed, his results agree with the TPS analysis. (Aeroelastic engineers normally work with equivalent airspeed.)

A Grob G-102, a single-seat sailplane similar to the G-103, has flown to 49,000 feet MSL. The materials, general shape and construction methods are similar. This gave the team confidence in the G-103.

Because analytical flutter studies are inexact, pilots should allow the greatest possible margin. They should fly at the minimum possible airspeed, avoid abrupt control movements and maintain hold of the stick at all times.

The weight of the Soar Eagle systems moved the center of gravity toward the forward limit for all configurations. Thus, flight at minimum speed required full aft (nose up) trim. Because most flight in wave conditions is at slow speeds, moving the center of gravity toward the aft limit would improve efficiency. This would mitigate the trim drag from the required aft stick.

Grob Sailplanes Inc., the manufacturer of the G-103, discusses the use of "spin weights" in the flight manual (2). These weights move the center of gravity aft enough to allow the sailplane to spin. The test team should investigate

procuring weights to move the Soar Eagle center of gravity aft.

A secondary goal of Soar Eagle is the two-place absolute altitude record of 44,255 feet MSL. This would require experimental category operations because two-pilots would put the weight over the normal category limit of 1,279 pounds. The Grob factory has approved operations to 1,500 pounds in the experimental category with some restrictions (11).

AVIONICS

The Grob has a VHF radio antenna molded into the fiberglass of the vertical tail. The test team tested the tuning of the antenna and found it was deficient. The standing wave ratio (SWR) was best at 123.4 megahertz (MHz). Frequencies more than three megahertz from 123.4 MHz had unacceptable SWR ratios. As expected, ground stations heard transmissions best if the frequency was near 123.4 MHz. Thus, the team preferred 123.55 MHz as a mission frequency.

A test of the transmitted field strength showed that it was not uniform. During operations the radio received well on all frequencies. The position of the station relative to the heading of the glider also made a significant difference. When the Grob was north of Inyokern, using remote transceivers near the glider resulted in the best communications.

A better antenna is probably the easiest way to improve communications. A dipole antenna mounted inside the vertical fin along the rudder hinge line has worked well in other sailplanes (3:46-47)

The transponder, altitude encoder, C-band beacon and turn needle worked as designed.

The LOX quantity indicator worked well. The system provided a reading within two seconds of pushing the test button. Fifteen minute test intervals were adequate to monitor consumption rates.

Even with the solar panels, the batteries needed charging at the end of a mission. During normal weekday duty hours, the battery shop can "top charge" the batteries in about four hours. Another set of batteries or in-house charging capability would speed turn around and reduce the chance of missing a record opportunity.

LIFE SUPPORT SYSTEMS

The life support systems were outstanding. The pressure suit was comfortable. Even when the suit inflated, it allowed good mobility. The tube which carried the exhausted air aft minimized the moisture in the cockpit, preventing frost on the canopy. This solved a safety problem which has plagued other wave projects. However, suit preflight checks were possible only with the cover removed. Reinstalling the cover was difficult as it required the threading of two blind screws.

The face heat worked well. The battery capability required to support it was adequate for short flights. Since the orientation of the Sierra wave required westerly sailplane headings, the sun was normally on the pilot's left. It provided enough solar energy to keep the left side of the visor clear. This allowed the pilot to fly with little or no visor heat. Also, increased oxygen flow reduces visor fogging. In an emergency, the pilot could intentionally vent oxygen through the drinking port. Although this rapidly depletes the oxygen supply, it can allow the pilot to make a safe letdown.

LOX use rates at low altitude were 1.0 liters per hour. At high altitude, the rate was less than 0.5 liters per hour. These rates were higher than expected. All missions should begin with a full LOX bottle. If the quantity indicator system is inoperative, pilots should limit flights to 4.0 hours.

The team aborted flights when the LOX remaining was down to 1.0 liters. This allowed sufficient quantity for return to base from as far north as Mount Whitney.

One concern of the team was how well the full pressure suit protected the pilot from hypothermia. The pressure suit and required undergarments tended to overheat the pilot during launch. At altitude, the perspiration from overheating caused pilots to feel cold.

The team did several things to help. Suit ventilation from walk around bottles was used up until canopy closure, reducing this heat stress as much as possible. The air vents in the nose and the canopy helped if left open at lower altitudes. Wearing polypropylene underwear, socks and glove liners also helped. Polypropylene is "wickable," meaning that it does not hold moisture. It tends to wick moisture away from the body. This meant that the pilot was not as susceptible to the moisture from low altitude sweating.

Experience showed that solar heating is adequate to keep the upper body and arms warm. The feet, which are in footwells, are the only extremity that ever got cold during flight. The team found that feet stayed satisfactorily warm with layered protection. The first layer was socks of a wool/polypropylene blend inside the pressure suit booties. Outside the booties, the team used thick wool socks and Type N-1B extreme cold weather boots. Finally, the team lined the inside of the footwell with Ensolite[®], a foam about one-half inch thick. Of these layers, substituting ski boot liners for the thick wool socks might be better.

One pilot tested electric socks powered by 1.5 volt batteries. Although they helped, the cold environment quickly sapped the batteries. The best setup would power the socks from a 1.5-volt transformer wired to the aircraft battery.

The life support personnel felt that the Security 150 parachute was not the best available. The team used it because it was the only one available that fit into the cockpit. The parachute test branch at Edwards has test-jumped a National 490 parachute. They determined it was better than the Security 150. Soar Eagle should incorporate the National 490 as soon as hardware modifications are complete.

OPERATIONS

Operationally, the key to catching a wave was being ready when it occurred. Since the Grob was not available continuously, weather forecasting was important to being ready.

Forecasting record wave conditions is difficult. The team looked at winds aloft forecasts and balloon soundings. In particular, the 500 millibar charts ($\approx 18,000$ feet) were the primary ones used to make general forecasts. The team looked for westerly flow and at least a 30 meter pressure level change from the north to south end of California.

Mr. Doug Armstrong of the National Weather Service hypothesizes that the conditions that exist at the tropopause will cap the wave (6). The experience of the test team supported Mr. Armstrong's theory. If the theory is correct, the frequency of mountain waves extending above 50,000 feet in the Soar Eagle operating area is very low. After learning of the theory in January 1987, the team watched the height of the tropopause closely. The normal height at Edwards ranges between 35,000 and 40,000 feet. On the day of the 42,200 foot flight, the Edwards tropopause was at 42,000 feet. In July 1987 the tropopause was above 50,000 feet on two occasions.

However, the low level winds were not strong enough to cause mountain waves.

Experience shows that when the next record wave occurs, the sub-tropical jet stream will probably pass north of Mount Whitney. The tropopause will be above 50,000 feet, and the winds will be westerly with a true speed of approximately twice their level in thousands of feet. For instance the 30,000 foot wind will be about 60 knots. Any abrupt change in direction or magnitude will cap the lifting action.



Figure 9. A "Good" 500 Millibar Weather Chart

What this means is that the wave must have relatively constant energy at each level. As the air density decreases with altitude, the reported wind speed, which is a true speed, must increase if the wave energy is to remain constant. If the wind speed was reported in units analogous to indicated airspeed, the desired speed would be constant with altitude.

The test plan (5) restricted missions to AFFTC Regulation 55-2 (4) wind limits. These limits require cancelation of flight when steady winds exceed 25 knots and/or gusts exceed 35 knots. To date, these limits have not hampered Soar Eagle

operations. However, these limits could be a factor during record wave conditions.

The test plan required the following pilot training: academic and altitude chamber pressure suit training, sailplane egress with pressure suit, parachute landing fall training and two local practice flights wearing the pressure suit. The experience of the test team showed that this was a good training program.

Additional glider pilot experience that was helpful included: off field landing experience, wave flying, cross country and an intimate knowledge of the local flying area.

Operating from the T-46 hangar and lakebed made record attempts much easier. The cooperation of all agencies from air traffic control to the flight surgeon was outstanding.



Figure 10. The Sierra Mountain Wave on 18 March 1987

Chapter Five

CONCLUSIONS

Project Soar Eagle is a mature project. The project sailplane has flown to 42,200 feet. The environment encountered at this altitude was as hostile as the conditions at record altitudes. This is the best argument that the Grob G-103 and its systems can safely make a record flight.

The following recommendations will increase the chances of success:

1. Acquire additional batteries to allow quick turnarounds.
2. Install a new aircraft radio antenna to improve effective transmission power.
3. Add trim weight to make the Grob G-103 more efficient.

The following would insure safe flight:

1. Continue to carefully inspect the canopy for cracks before each mission.
2. Continue to observe conservative indicated airspeeds, avoid abrupt control movements and maintain hold of the stick at high altitudes.
3. Incorporate the National 490 parachute.

The bottom line is that given suitable weather, the Soar Eagle Project can safely achieve the world absolute altitude record for gliders.

ACKNOWLEDGMENTS

The following have made significant contributions to Project Soar Eagle through July 1987:

Pilots--Maj William Jabour, Maj Lawrence Davis, Lt Col Kent Crenshaw, Capt Chris Glaeser, Maj James Payne

Life support--Mr Dick Cook, Mr Bob Stahl, MSgt David Arnold, SSgt Vernon Bergstedt, SSgt Rick Benson, SRA Mike Baldwin, A1C Jim Powers

Engineering--Maj Pat Talty, Maj Gary Aldrich, Capt Dave Neyland

Sheet metal--Mr Dwight Joy

Towing--Maj Ray Narleski, Capt Greg Davis, Mr Richard Binbrook

Operations--TSgt Terry Healy, Amn Larry Booth

Sailplane owner--Mr Bill Jones

Sailplane and towplane contractor--Skylark North Glider-port

Special thanks to General Dynamics for loan of heat exchanger and oxygen quantity indicator.

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APPENDICES

SOAR EAGLE GROB G-103 WIRING DIAGRAM



Appendix B

Phase One Flight History

Date	Pilot	Max Altitude	Sailplane	Mission
19 Dec 83*	Jabour	N/A	Blanik N157AS	Checkout
11 Jan 84*	Davis	N/A	Blanik N157AS	Checkout
09 Feb 84*	Jabour	13,000	Blanik N157AS	Record try
10 Feb 84*	Jabour	14,000	Blanik N157AS	Record try
24 Feb 84*	Davis	30,000	Blanik N157AS	Record try
29 Feb 84*	Jabour	32,000	Blanik N157AS	Record try
26 Oct 84**	Glaeser	N/A	Blanik N157AS	Checkout
30 Oct 84**	Crenshaw	N/A	Blanik N157AS	Checkout
19 Apr 85**	Glaeser	34,600	Blanik N157AS	Record try
20 Apr 85**	Crenshaw	21,000	Blanik N157AS	Record try
21 Apr 85**	Glaeser	28,600	Blanik N157AS	Record try
08 Nov 85**	Glaeser	24,000	Blanik N70AS	Record try
09 Nov 85**	Glaeser	28,000	Blanik N70AS	Record try
21 Nov 85**	Glaeser	Nil	Blanik N70AS	Record try

* Reference 8, Table C1

** Reference 7

Appendix C

Phase Two Flight History

Date	Pilot	Max Altitude	Sailplane	Mission
11 Feb 86*	Payne	N/A	Blanik N70AS	Checkout
12 Apr 86*	Payne	38,800	Grob N38366	Record try
16 Apr 86**	Glaeser	35,600	Grob N38366	Record try
15 May 86*	Payne	Nil	Grob N38366	Record try
20 May 86*	Payne	16,500	Grob N38366	Record try
21 May 86*	Payne	31,700	Grob N38366	Record try
08 Mar 87*	Payne	23,000	Grob N38366	Record try
14 Mar 87*	Payne	21,600	Grob N38366	Record try
18 Mar 87*	Payne	42,200	Grob N38366	Record try
11 Apr 87*	Payne	24,100	Grob N38366	Record try
01 May 87*	Payne	28,000	Grob N38366	Record try
17 Jul 87*	Payne	26,700	Grob N38366	Record try

* Reference 10

** Reference 7

Appendix D

GLOSSARY

Item	Definition
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
C-band	C frequency band (≈ 5040 megahertz)
CB	Circuit Breaker
DIR	Digital Instrumentation Radar
FAA	Federal Aviation Administration
FAI	Fédération Aéronautique Internationale
fpn	Feet per minute
KEAS	Knots Equivalent Airspeed
KIAS	Knots Indicated Airspeed
knots	Nautical miles per hour
kph	Kilometers per hour
LOX	Liquid oxygen
M	Meters
MHz	Megahertz
MSL	Mean Sea Level
N-number	FAA aircraft registration number
PN	Part Number
psi	Pounds per square inch
SWR	Standing Wave Ratio
TPS	USAF Test Pilot School
TSO	FAA Standard Technical Order
VHF	Very High Frequency (118-137 MHz)
UHF	Ultra High Frequency (225-400 MHz)
USAF	United States Air Force
vdc	Volts direct current

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